# NORTHSTAR UNIT 7 SITE REPORT

May 2008

## INTRODUCTION

This report describes monitoring and results from the Northstar Unit 7 site (Unit 7) at Northstar-at-Tahoe Resort (Northstar), a year-round resort. The Northstar Resort is located in Placer County, California, just off Highway 267 in between Truckee and King's Beach (Figure 1). The Unit 7 plots are located in a residential area just off Big Springs Drive, northwest of the Village at Northstar. The Unit 7 monitoring site consists of three discrete slopes with two different treatments. The Overlook East and Hydroseed plots span the southwest corner of the intersection of Big Springs Drive and Overlook Place. Overlook West lies at the west end of Overlook Place, on the south side of the street near the cul-de-sac (Figure 2).


**Figure 1. Satellite image showing the location of Northstar Unit 7.**

The Overlook East and West plots were both constructed in November 2001 and the Hydroseed plot was treated in 1999. The Hydroseed plot surface treatment was similar to the Caltrans Erosion Control Type D treatment. These plots were monitored to compare the erosion control performance of surface hydroseed treatments, such as those used in the Hydroseed plot, with "full treatment" plots. "Full treatment", which was performed at the Overlook East and West plots, includes tilling, addition of organic matter, fertilizer, native seeds, and mulch. Although these plots were not part of a Caltrans project, the monitoring results and treatment recommendations from these sites can be applied to Caltrans sites with similar environments and treatments. The Northstar Unit 7 plots capture the variability of a large scale erosion control project because they encompass a larger area than most of the test plots constructed for the Caltrans project. Monitoring was conducted at Unit 7 during five seasons, starting in 2002. The historical data will be used to help establish an understanding of the restoration potential and the ecological trajectory of restoration sites.

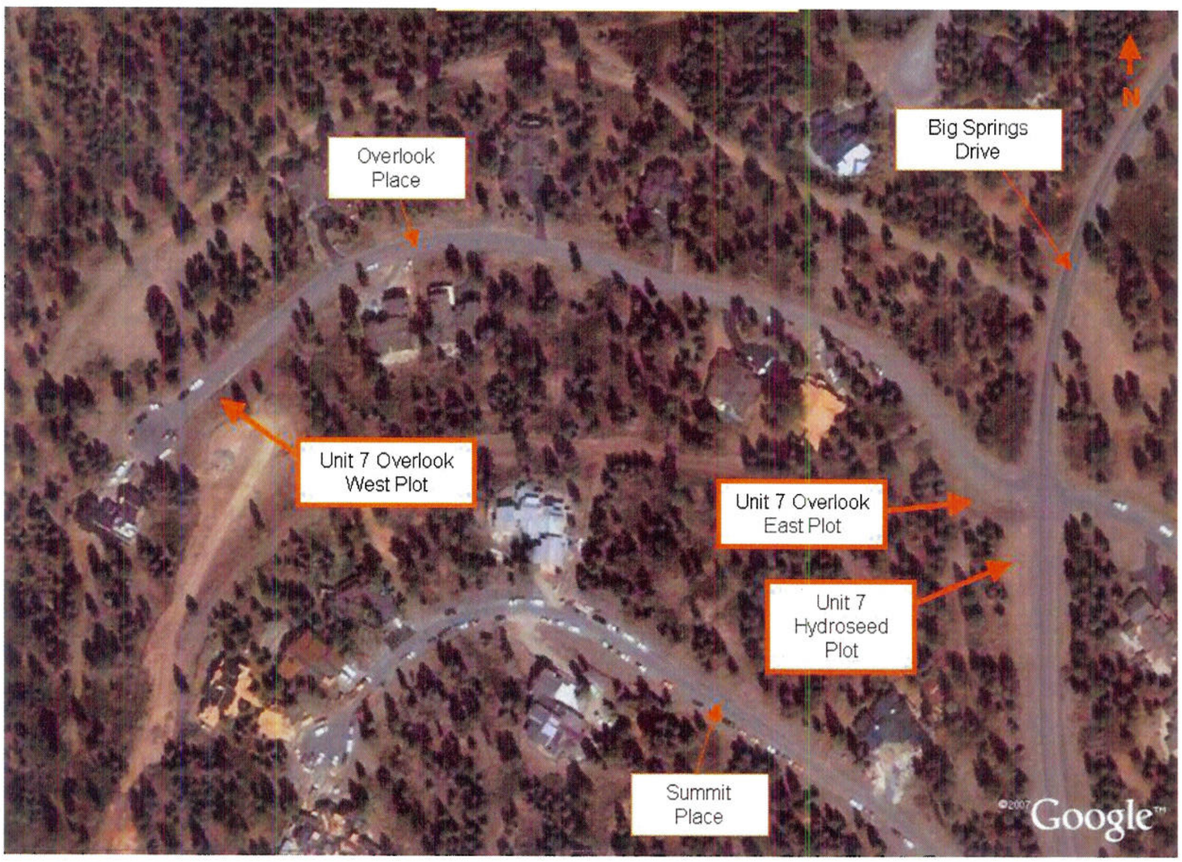


**Figure 2. Satellite image showing the location of the Overlook East, Overlook West, and Hydroseed plots at Northstar Unit 7.**

## PURPOSE

These plots were monitored to determine whether a difference exists in the erosion control capacities of the Hydroseed plot, with a surface hydroseed treatment (similar to Caltrans Erosion Control Type D), and the Overlook East and Overlook West plots, which incorporated a soil loosening technique, an addition of composted wood waste (woodchips), organic fertilizer, native seeds, and pine needle mulch. The following measurements were used to determine which plots have the greatest capacity for erosion control: infiltration rate, sediment yield, soil density, soil nutrient levels, foliar cover by plants, ground cover by mulch, and soil shear strength. Treatment recommendations will be made based on the monitoring results.

## SITE DESCRIPTION

The Overlook East and West plots are positioned on a north-facing, 27 degree cut slope in a residential neighborhood. The soil originated from volcanic parent material. The soil is classified as a sandy loam with approximately 60% sand, 20% silt, and 20% clay. All plots have very little canopy cover and are at an elevation of approximately 6,500 feet above mean sea level. The Hydroseed plot, which is at the same elevation and faces northeast, has a slope angle of 24 degrees. The solar exposure for all plots averages between 73 and 78%. Surrounding vegetation consists of an over story of white fir (*Abies concolor*) and Jeffrey pine (*Pinus jeffreyi*) with an under story of greenleaf manzanita (*Arctostaphylos patula*), bitterbrush (*Purshia tridentata*), tobacco brush (*Ceanothus velutinus*) and bitter cherry (*Prunus emarginata*).

## METHODS AND MATERIALS

### Treatments

The treatments at Overlook East and West were completed in 2001. Figure 3 and Figure 4 show Overlook East and West before and after they were treated. Originally, both plots were treated with the same surface hydroseed treatment used in the Hydroseed plot.

**Figure 3. Unit 7, Overlook East and West, pre-treatment.**

**Figure 4. Unit 7 Overlook West, post-treatment.**

In 2001, both plots were tilled to a depth of 8 to 12 inches (20 to 30 cm), first using a backhoe with teeth extensions, then with a reach forklift. Four inches (10.2 cm) of aged wood waste (woodchips) were tilled into the soil and then 1,500 lbs/acre (1,684 kg/ha) of Biosol was incorporated. A native seed mix was lightly raked into the soil at a rate of 110.5 lbs/acre (124 kg/ha) and a Shred-vac blower was used to spread 1.25 inches (3.2 cm) of pine needle mulch (Table 1). Tackifier was then applied.

**Table 1. Seed mix composition.**

| Common Name | Scientific Name | Percent in mix (%) |
|---|---|---|
| Mountain brome | *Bromus carinatus* | 31.7 |
| Blue wildrye | *Elymus glaucus* | 31.7 |
| Squirreltail | *Elymus elymoides* | 31.7 |
| Yarrow | *Achillea millefolium* | .5 |

The Hydroseed plot was treated in 1999 using a standard hydroseed surface treatment that is similar to Caltrans Erosion Control Type D.

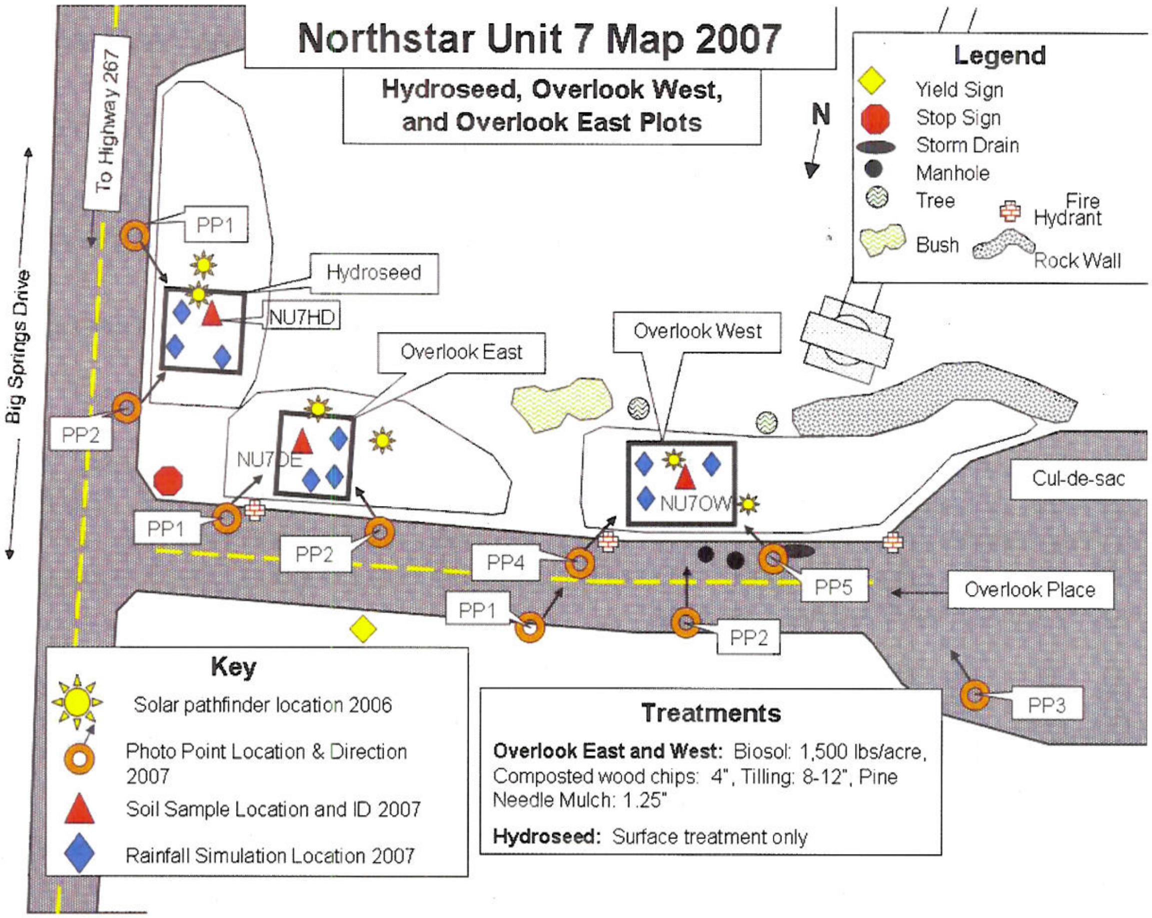


**Figure 5. Monitoring and treatment map of Northstar Unit 7 showing photo point, rainfall, solar pathfinder, and soil sample locations in 2007.**

## Monitoring

In 2007, the following monitoring data was collected at Unit 7: foliar and ground cover, soil density, soil nutrient status, infiltration rate, sediment yield, soil shear strength, and general site characteristics. When applicable and available, historical data will be presented with the 2007 monitoring data.

All monitoring was conducted in metric units, while treatment applications were calculated in English units. In the text, both metric and English units are given.

### Cover

Cover point monitoring is a statistically defensible method of measuring plant and foliar cover (referred to as either "plant cover" or "foliar plant cover"), plant composition, and mulch cover.

Cover was measured at both Overlook East and West in 2002, 2003, 2005, and 2007, and at the Hydroseed plot in 2003, 2006, and 2007. Cover was also measured at Overlook East in 2006, but not at Overlook West.

Cover was measured using the cover point method along randomly located transects.[1] The cover pointer consists of a metal rod with a laser pointer mounted 3.3 feet (1 m) high. After the rod was leveled in all directions, the button on the laser pointer was depressed and two cover measurements were recorded (Figure 6 and Figure 7):

1) the first hit cover, which represents the first object intercepted starting from a height of 3.3 feet (1 m) above the ground
2) the ground cover hit

The first hit cover measures the foliar cover by plants (leaves and stems). It does not measure the part of the plant actually rooted in the ground. The first hit vegetation is then moved aside and a ground cover hit (second hit) measures the presence of litter/mulch, basal (or rooted) plant cover, rock and woody debris and/or bare ground.

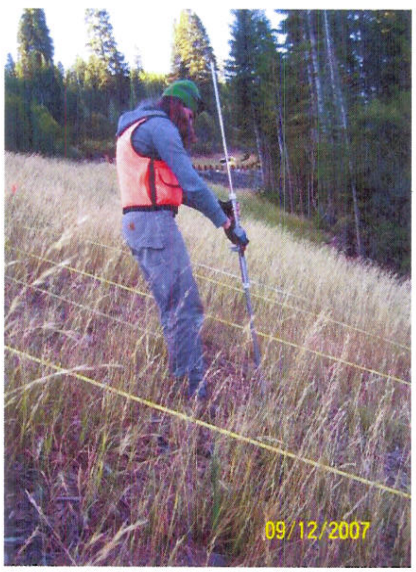


**Figure 6. Cover pointer in use along transects.**

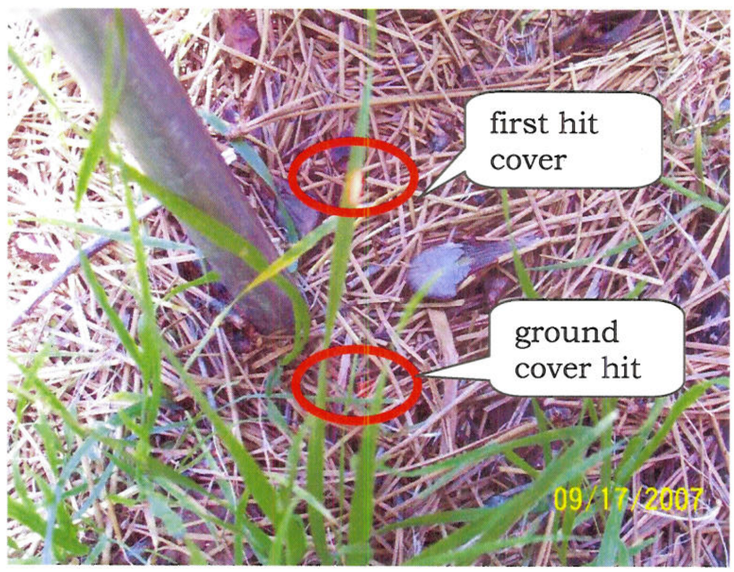


**Figure 7. Cover pointer rod with first hit cover and ground cover hit by the laser pointer. The laser pointer hits are circled in red. The first hit cover is a native grass and the ground cover hit is pine needle mulch.**

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[1] Hogan, Michael. Luther Pass Monitoring Report: Plant and Soil Cover Monitoring for Evaluating Sediment Source Control Success in the Lake Tahoe Basin. 2003. South Lake Tahoe, CA, Lahontan Regional Water Quality Control Board.

Total ground cover comprises all cover other than bare ground. Plant cover both on the ground and foliar was recorded by species and then organized into cover groups based on four categories: lifeform (herbaceous/woody), perennial/annual, native/alien (2007 only), and seeded/volunteer (2007 only). Perennial herbaceous species includes perennial seeded grasses and forbs, native grasses and forbs and non-native grasses and forbs. Annual herbaceous species include native annuals such as knotweed (*Polygonum sp.*) and invasive species such as cheatgrass (*Bromus tectorum*). Woody species are trees and shrubs, both native and introduced. In 2007, each species was then classified based on whether it is native to the Tahoe area, and whether it was seeded during treatment. Ocular estimates were recorded by species in 2007, which is presented in Appendix A. Species of interest are species that were seeded and problem species such as cheatgrass. The ocular estimate of cover at each plot includes many species not hit using cover point sampling. The species list, as well as the ocular estimates of cover, is presented in Appendix A.

## Soil and Site Physical Condition

### Soil Density

In 2006 and 2007, soil density and soil moisture were measured along the same transects as the cover point data for all of the plots. A cone penetrometer was used to measure depth to refusal, which was used as an index for soil density. The cone penetrometer with a ½ inch diameter tip was pushed straight down into the soil until a maximum pressure of 350 pounds per square inch (psi) (2,411 kPa) was reached (Figure 8 and Figure 9). The depth at which that pressure was reached was recorded as the depth to refusal (DTR). These depth measurements were used as an index for soil density.


**Figure 8. Cone penetrometer dial, showing pressure applied in pounds per square inch.**

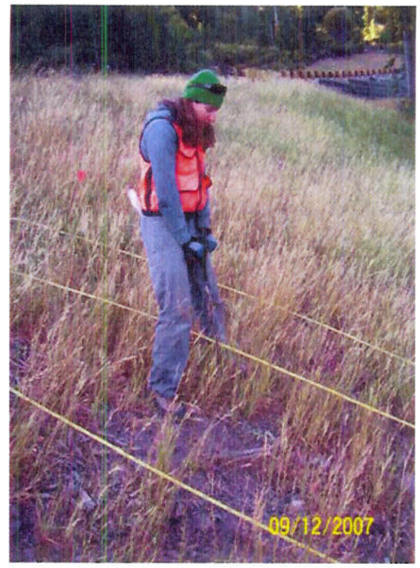


**Figure 9. Conducting cone penetrometer readings along transects.**

Soil Moisture

A hydrometer was used to measure volumetric soil moisture content adjacent to the penetrometer readings at a depth of 4.7 inches (12 cm) (Figure 10).

Shear Strength

High soil strength may be related to a soils resistance to mass slope failure under high moisture conditions. Soil strength can be attributed to one or all of these soil characteristics: internal structure of the soil, woody material in the soil, dense plant roots in the soil, or soil compaction. It is important to know how each soil derives its strength to determine whether its strength will be beneficial in preventing erosion. In laboratory tests, the density of plant roots has been shown to increase soil strength in laboratory tests.[2]

In 2007, soil strength was tested along cover point transects in the same manner as soil density and soil moisture. A hand-held shear vane with 1.5 inch (3.8 cm) long blades was pushed into the soil to a depth of 3 inches (7.6 cm) and turned until the soil could no longer resist the force exerted by the blades and the soil structure fractured or deformed (Figure 11). This force was then recorded as the "shear stress" in kilopascals (kPa). Forty kilopascals was the maximum force the shear vane could measure. Shear stress values greater than 40 kPa were recorded as 40 kPa.

[2] Tengbeh, G.T. 1993. The Effect of Grass Roots on Shear Strength Variations with Moisture Content. *Soil Technology*. Vol. 6. pp. 287-295.

Solar exposure

Solar radiation measurements were taken at each plot using a Solar Pathfinder (Figure 12). Solar input affects evaporation rates and soil temperature, which may affect time of seed germination, germination rate, rate of plant growth and soil microbial activity. It is an important variable to consider when monitoring plant growth and soil development.

**Figure 10. Conducting soil moisture readings along transects.**

**Figure 11. Soil shear strength tester in use.**

**Figure 12. Solar pathfinder in use.**

**Soil Nutrient Analysis**

Successful re-vegetation requires nutrient capital storage in the soil. Readily available sources of nitrogen need to be present and sufficient organic matter and a healthy microbial community are necessary to provide a long term source of nitrogen. Previous studies of soil nutrient levels at re-vegetation sites throughout the Tahoe area found that sites with high plant cover had significantly higher soil nutrients over the long term than soils with lower soil nutrient levels.[3] Total Kjeldahl nitrogen and organic matter were used as indicator of soil health in this study. Total Kjeldahl nitrogen (TKN) is a measure of readily available nitrogen.

[3] Claassen, V. P. and Hogan, M. P. Soil Nutrients Associated with Revegetation of Disturbed Sites in the Lake Tahoe Basin. Restoration Ecology. 2002 Jun; 10(2):195-203.

In 2006 and 2007, soil sub-samples were taken from beneath the mulch layer at a depth of 12 inches (30 cm) on each of the three plots (Figure 5). Three soil sub-samples were taken from each location of the mineral soil beneath any mulch layer to a depth of 12 inches (30 cm). These sub-samples were combined and sieved to remove any material larger than 0.08 inches (2 mm) in diameter, and then sent to A&L Laboratories (Modesto, CA) for S3C nutrient suite, total Kjeldahl nitrogen (TKN), and organic matter analysis. A sample from the Hydroseed surface treatment site and a full treatment sample were analyzed for particle size distribution.

**Figure 13. Soil sub-sample collection.**

### Rainfall Simulation

In 2006 and 2007, rainfall simulation was conducted at each plot (Figure 5). The rainfall simulator "rains" on a square plot from a height of 3.3 feet (1 m) (Figure 14 and Figure 15). The rate of rainfall is controlled, and runoff is collected from a trough at the bottom of a 6.5 square feet (0.6 $m^2$) frame that is pounded into the ground. The volume of water collect is measured; then the volume of infiltration is calculated by subtracting the volume of runoff from the total volume of water applied to the plot. If runoff was not observed during the first 30 minutes, the simulation was stopped. The average steady state infiltration rate was calculated and will hereafter be referred to as "infiltration rate". The collected runoff samples were then analyzed for the average steady state sediment yield (hereafter referred to as "sediment yield").

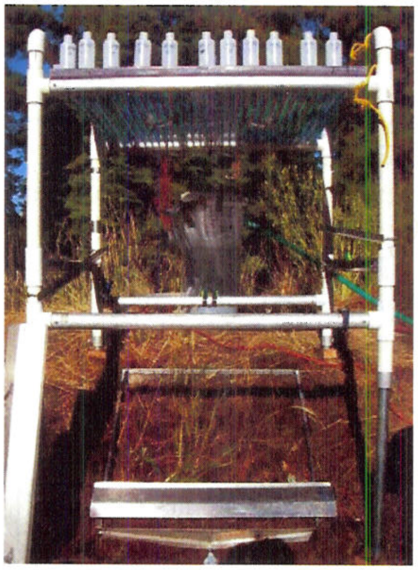

**Figure 14. Rainfall simulator and frame**

**Figure 15. The rainfall simulator and frames at the Overlook West plot.**

A cone penetrometer was used to record the DTR surrounding the runoff frames before rainfall simulations. The 2006 DTR pre-rainfall values were taken at a maximum pressure of 250 psi (1,724 kPa) and the 2007 DTR values that were taken at 350 psi (2,413 kPa), are presented in this report. Soil moisture was also measured in each runoff frame prior to conducting the rainfall simulations. After rainfall simulation, at least three holes were dug with a trowel to determine the depth to wetting front, which shows how deeply the water infiltrated within the frame. In 2007, at least 9 holes were dug to measure the depth to wetting.

Different rainfall rates were applied to different plots depending on their propensity to runoff. The initial rainfall rate applied to the test plots was 2.8 inches/hour (71 mm/hr). If runoff was not observed, the rainfall rate was increased to 4.7 inches/hour (120 mm/hr) until runoff was observed or all the water was infiltrated. During one simulation in 2007, the rainfall rate was increased to 3.8 (96 mm/hr) after runoff was not observed at 2.8 inches/hour (71 mm/hr). The rainfall rate of 2.8 inches per hour (71 mm/hr) is more than twice the intensity of the 20 year, 1 hour "design storm" for the local area.

## RESULTS AND DISCUSSION

### Rainfall

The two year average sediment yield at the Hydroseed plot was 32 times higher than the two year average at the full treatment Overlook plots (Figure 16, Figure 17, and Figure 18). Sediment yield for the Hydroseed plot was as high as 820 lbs/acre/in (362 kg/ha/cm), while the highest sediment observed on full treatment plots was 101 lbs/acre/in (46 kg/ha/cm). The two-year average steady state sediment yield for the Hydroseed plot was 816 lbs/acre/in (360 kg/ha/cm), versus 25 lbs/acre/in (11 kg/ha/cm) for Overlook East and West plots combined.

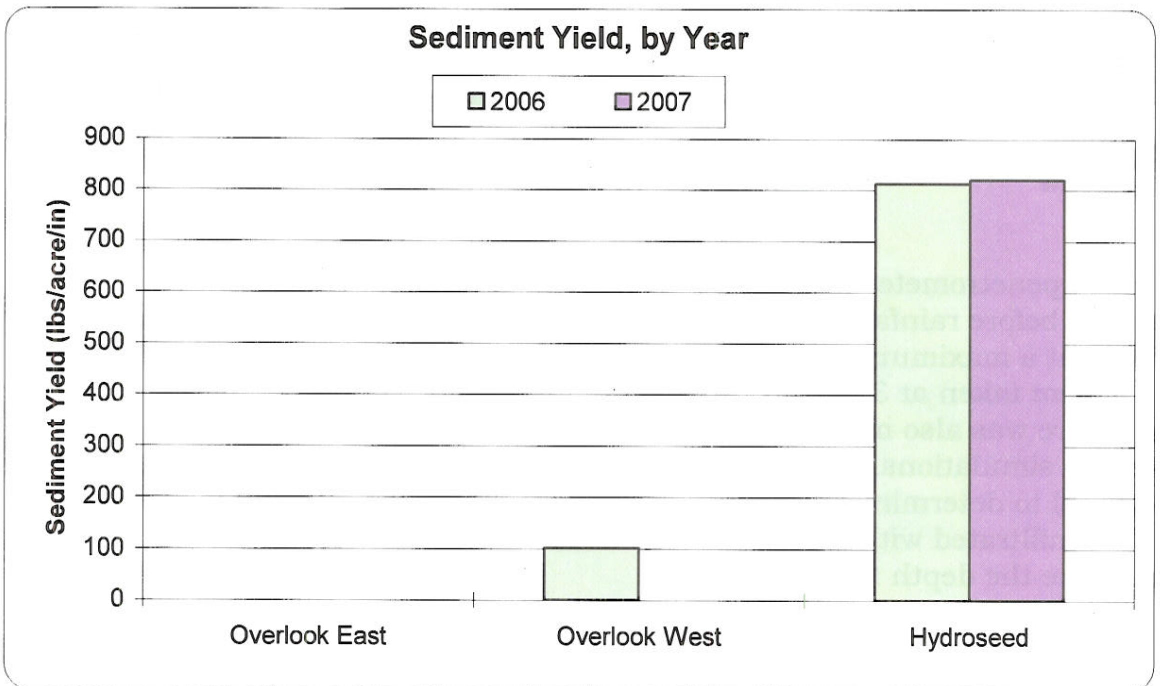


**Figure 16. Sediment Yield, by Year. The Hydroseed plot had the highest average sediment yield for two consecutive years.**

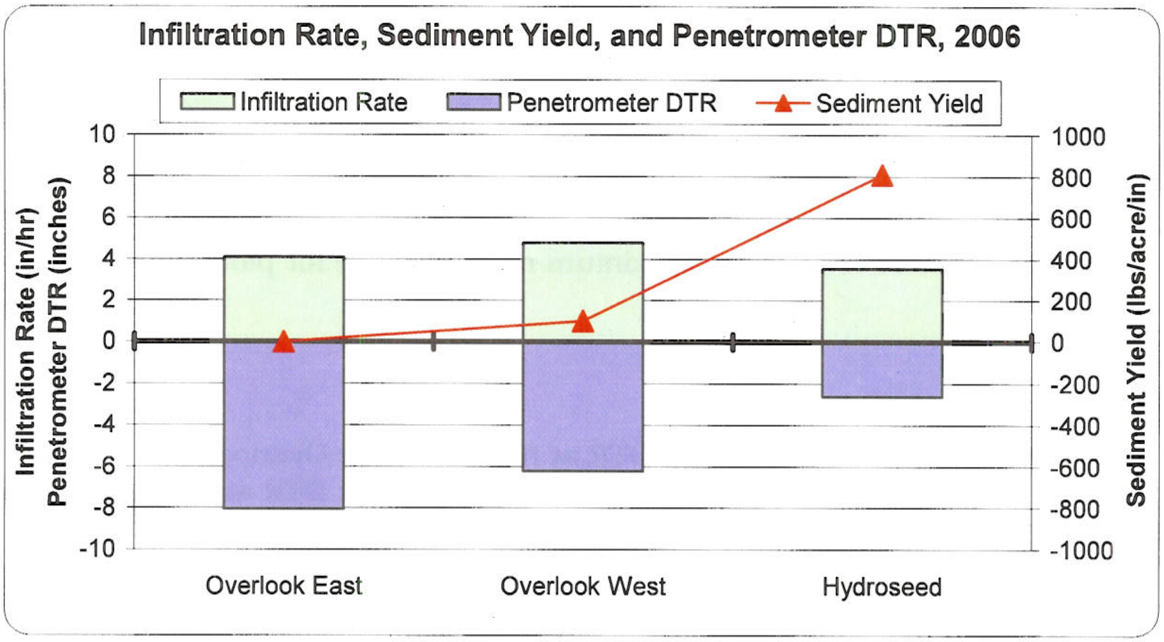


**Figure 17. Infiltration Rate, Sediment Yield, and Penetrometer DTR, 2006. The Hydroseed plot produced the highest sediment yield and had the lowest penetrometer DTR. Penetrometer DTRs were measured just outside the collection frame, prior to rainfall simulation.**

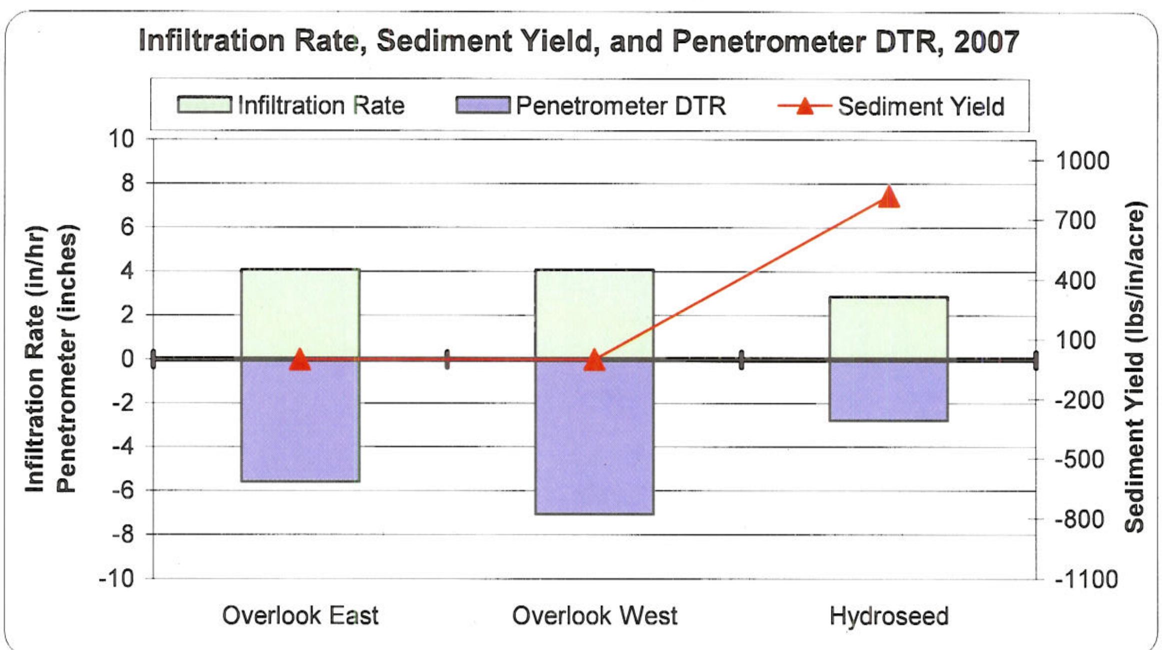


**Figure 18. Infiltration Rate, Sediment Yield, and Penetrometer DTR, 2007. The Hydroseed plot produced the highest sediment yield and had the lowest infiltration rate and penetrometer DTR for two consecutive years. Penetrometer DTRs were measured just outside the collection frame, prior to rainfall simulation.**

In addition to the high sediment yield and low penetrometer DTR at the Hydroseed plot, the infiltration rate was 1.4 times lower than the infiltration rates measured at the Overlook plots (Figure 17 and Figure 18). The average steady state infiltration rate for the Hydroseed plot was 3.2 inches/hour (81 mm/hour), while the average rate for the both Overlook East and West was 4.3 inches/hour (109 mm/hour). In most simulations, Overlook East and West plots did not produce runoff; therefore, the average steady state infiltration rates presented here are not the maximum rates possible for plots, only the tested rate.

## Soil Density

The two year average penetrometer DTR at full treatment Overlook plots was 2.5 times deeper than the two year average penetrometer DTR at the Hydroseed plot (Figure 19). The average penetrometer DTR at the Hydroseed plot was 3 inches (8 cm), while the average DTR at Overlook plots was 7 inches (18 cm). Low penetrometer DTRs have been associated with high sediment yields in previous research. Rainfall simulation results in similar soils showed a reduction in sediment yield in soils when penetrometer DTRs were greater than 4 inches (10 cm).[4]

Penetrometer DTRs measured along transects have been consistent at each site over the four year monitoring period (Figure 19). The average DTR for the Hydroseed plot was 3 inches (7.6 cm); for Overlook East, 7 inches (17.8 cm); and for Overlook West, 9 inches (22.9 cm). Variability in tilling most likely explains the difference in DTR between the Overlook East and Overlook West plots.

[4] Grismer, M.E. et al. Simulated Rainfall Evaluation at SunRiver and Mt Bachelor Highways, Oregon. Unpublished Data.

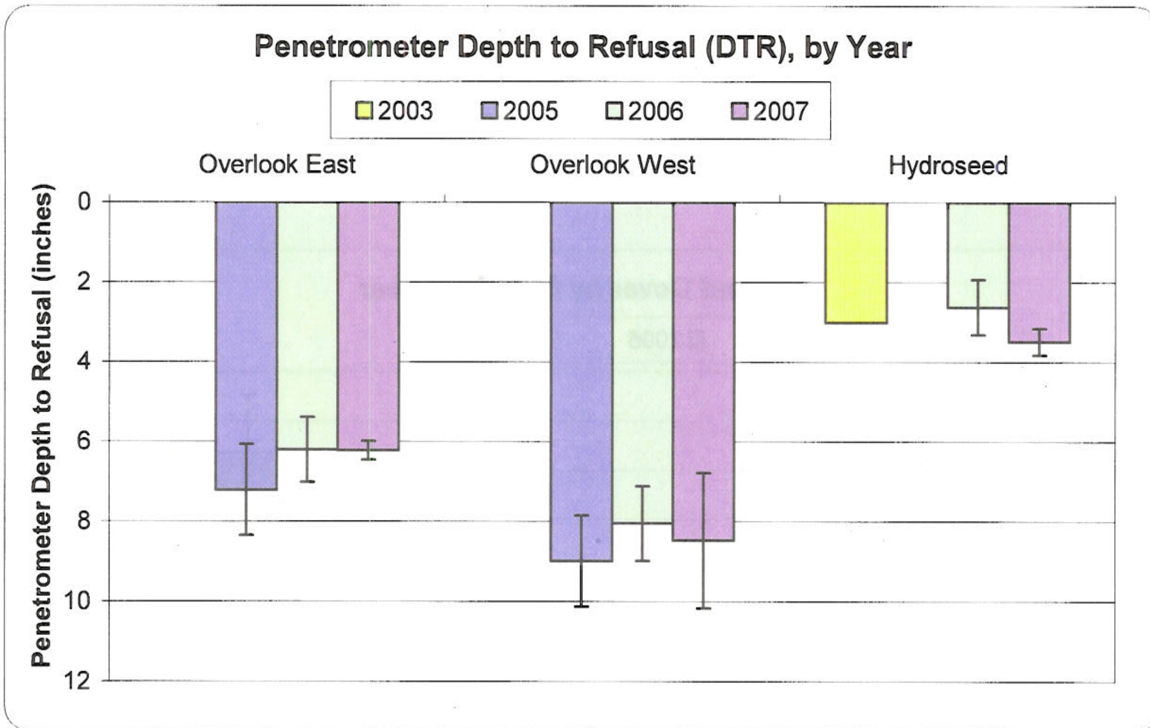


**Figure 19. Penetrometer Depth to Refusal (DTR), by Year. The Overlook plot DTRs were 2.5 times deeper than at the Hydroseed plot. Penetrometer measurements were collected along transects.**

## Cover

### Mulch Cover

Ground cover by mulch at the Hydroseed plot was 5 times less than ground cover by mulch at the Overlook plots (Figure 20). The Hydroseed plot also had the highest sediment yield. High mulch cover is often associated with sediment reduction as reported by Grismer and Hogan.[5] Mulch cover at the Hydroseed plot averaged 17% over two years, while the two year average ground cover by mulch at Overlook plots was 83% (Figure 20).

### Mulch Depth

Mulch depth at the Hydroseed plot was 3.5 times shallower than the mulch depth at the Overlook plots (Figure 20). In 2001, 1.25 inches (3.2 cm) of pine needle mulch was applied to the Overlook plots. In 2007, an average depth of 0.7 inches of mulch remained. The mulch depth at the Hydroseed plot, which

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[5] Grismer, ME, Hogan, MP. 2004. Evaluation of revegetation/mulch erosion control using simulated rainfall in the Lake Tahoe basin: 1. Method Assessment. *Land Degrad. & Develop.* 13:573-578.

had an unknown initial mulch application, was on average 0.2 inches (0.5 cm) deep in 2007.

Depth of mulch is crucial for erosion control. Many of the rainfall simulations conducted on native and treated sites with deep mulch did not produce runoff or sediment and had wetting depths that did not extend past the mulch layer.

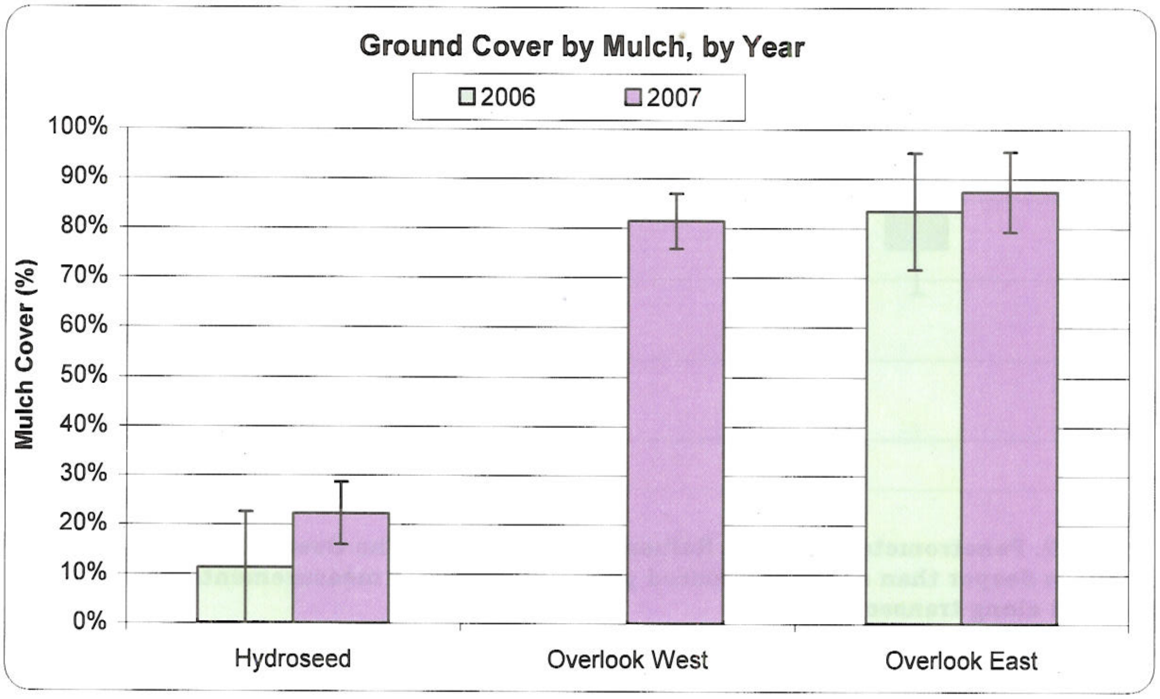


**Figure 20. Ground Cover by Mulch, by Year. The Hydroseed plot had the lowest cover by mulch. Measurements were taken at ground level. The Overlook West plot was not sampled for cover in 2006. Error bars denote one standard deviation above and below the mean.**

### Bare Soil

The proportion of bare ground at the Hydroseed plot was 8 times higher than at the Overlook plots (Figure 21). The Hydroseed plot had an average of 41% cover by bare soil over three seasons, while the Overlook plots, which had lower sediment yields, had an average of 5% bare soil (Figure 21).

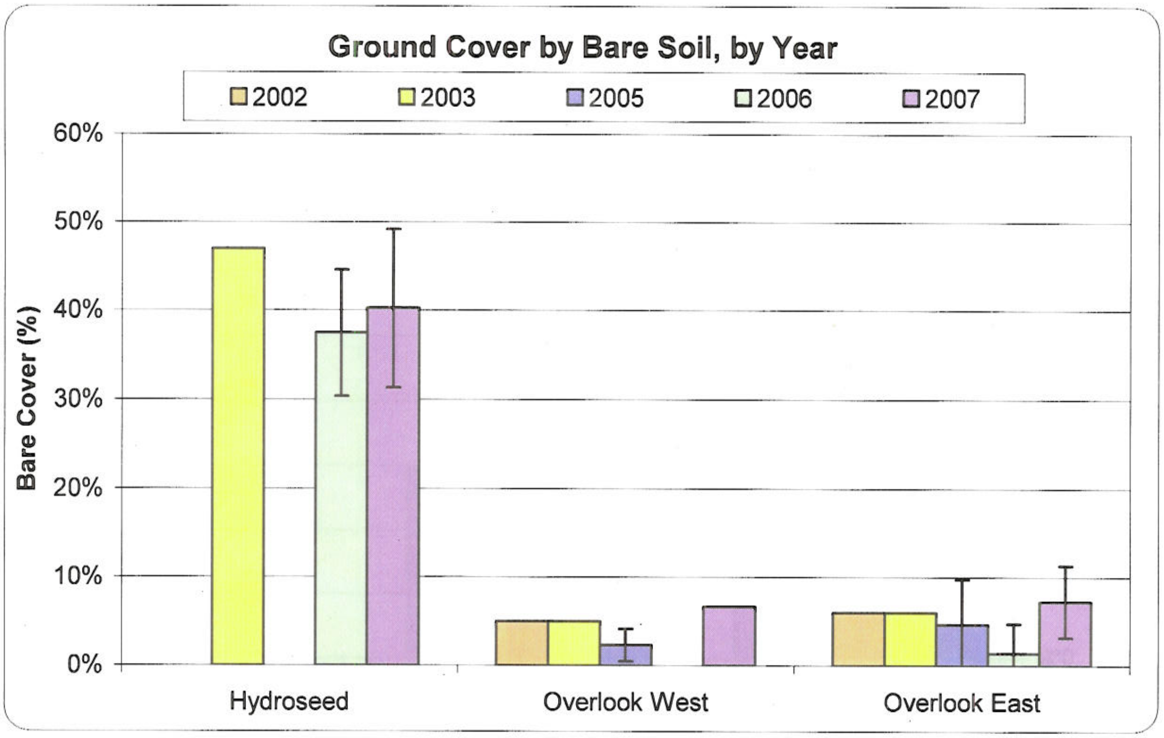


**Figure 21. Ground Cover by Bare Soil, by Year. The Hydroseed plot exhibited the highest bare cover over three years of sampling. Measurements were taken at ground level. Error bars denote one standard deviation above and below the mean. Standard deviations were not available for 2002 and 2003 cover data.**

## Plant Cover

Overlook East and Overlook West exhibited foliar plant cover that was twice the foliar cover at the Hydroseed plot over the six year monitoring period (Figure 22). The average foliar plant cover over five years of sampling was 32% at Overlook East. The four year average at Overlook West was 38%. In comparison, the three year average foliar plant cover at the Hydroseed plot was 18%. The same trends can be observed visually in Figure 23, Figure 24, and Figure 25.

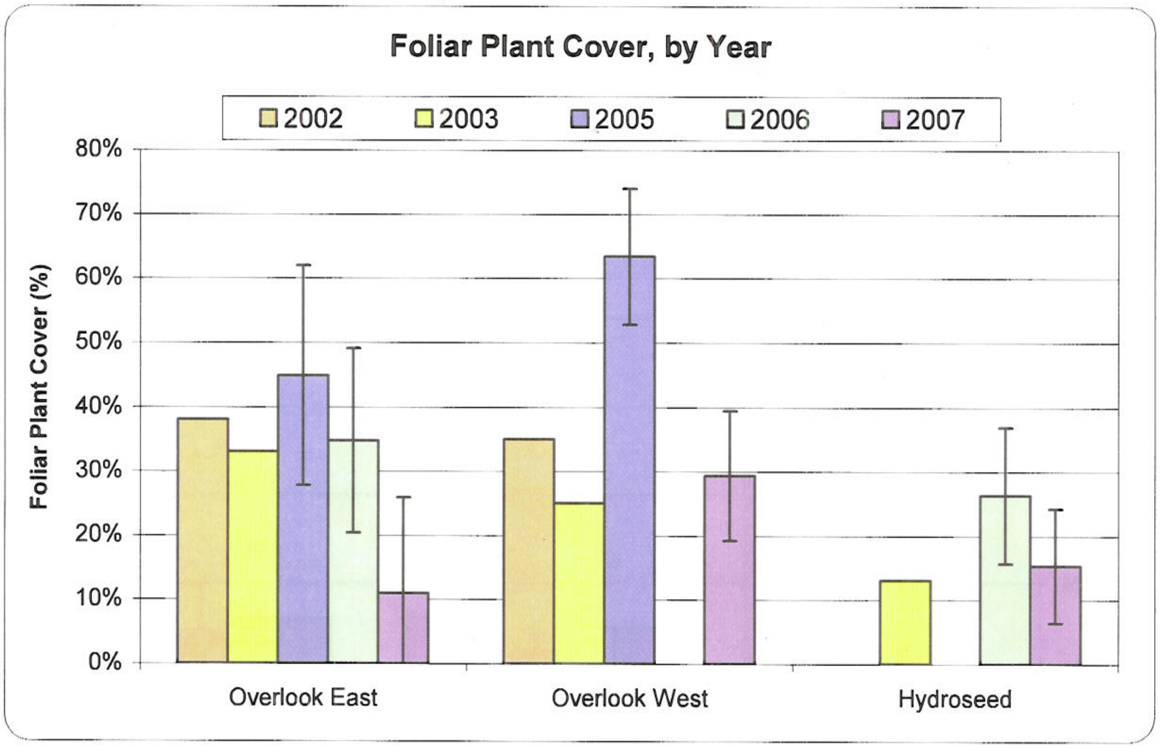


**Figure 22. Foliar Plant Cover, by Year. The Overlook East and West plots exhibited the highest plant cover. Plant cover was measured at the foliar (first hit cover) level. Foliar cover was not sampled at Overlook West in 2006.**


**Figure 23. Overlook East, 2007. High plant cover is evident.**

**Figure 24. Overlook West, 2006. High plant cover is evident.**


**Figure 25. Hydroseed, 2007. Low plant cover is evident when compared to the cover at Overlook East and West.**

Plant cover and composition at each plot varied by year and was most likely dependent on a combination of precipitation during the previous year, the month during which the plots were sampled, and the prevalence of late-season snowpack (Figure 22). The plant cover is generally known to increase during years with higher than normal precipitation and decrease in years with lower than normal precipitation. The average annual precipitation for the Tahoe Area is 30 inches (76.2 cm). Between 2002 and 2007, precipitation ranged from 22.5 to 51.1 inches (57 to 129 cm) during the water year (October 1 to September 30). It is ideal to measure plant cover during the peak of the growing season; however, this is not always possible. Early in the season, many of the plants, especially perennial species, have not yet appeared, leading to lower cover readings. Late in the season, many of the plants have dried up and some begin to lie on the ground, also reducing the foliar cover. Late-season snowpack can also lead to lower plant cover early in the growing season.

**Plant Composition**

The proportion of perennial cover at the Hydroseed plot and Overlook plots was similar in 2006, but the Hydroseed plot had a 2 times higher proportion of cover by perennial plants in 2007 when compared to the Overlook plots (Figure 26 and Figure 27). In 2006, The Hydroseed plot had 80% cover by perennial plants, while Overlook West had 72% cover by perennial plants. In 2007, the Hydroseed plot had 95% cover by perennial plant while the Overlook plots had an average of 46% cover by perennial plants. In other studies, high cover by perennial plants was related to low sediment yields. This was not the case at Unit 7, since the Hydroseed plot, which had the highest cover by perennial plants in 2007, also had a high sediment yield (820 lbs/acre/in or 361 kg/ha/cm).

Percent perennial plant cover decreased by 1.5 times between 2006 and 2007 at Overlook East and West plots (Figure 26 and Figure 27). In 2007, the percent of perennial plant cover at Overlook East and Overlook West was 50% and 41%, respectively. However, there was 72% perennial plant cover at Overlook East in 2006 (Overlook West was not sampled in 2006).

Perennial and total plant cover reduction across all plots may be a function of a higher than average water year in 2006, followed by a lower than average water year in 2007. The average annual precipitation in the Truckee area is approximately 31 inches (79 cm); however during the 2005-2006 water year (October 1, 2005 to September 30, 2006), the total precipitation was 51.1 inches (129 cm). During the 2006 to 2007 water year, the total precipitation was 22.5 inches (57.2 cm).[6]

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[6] http://www.wcc.nrcs.usda.gov/climate/avg/

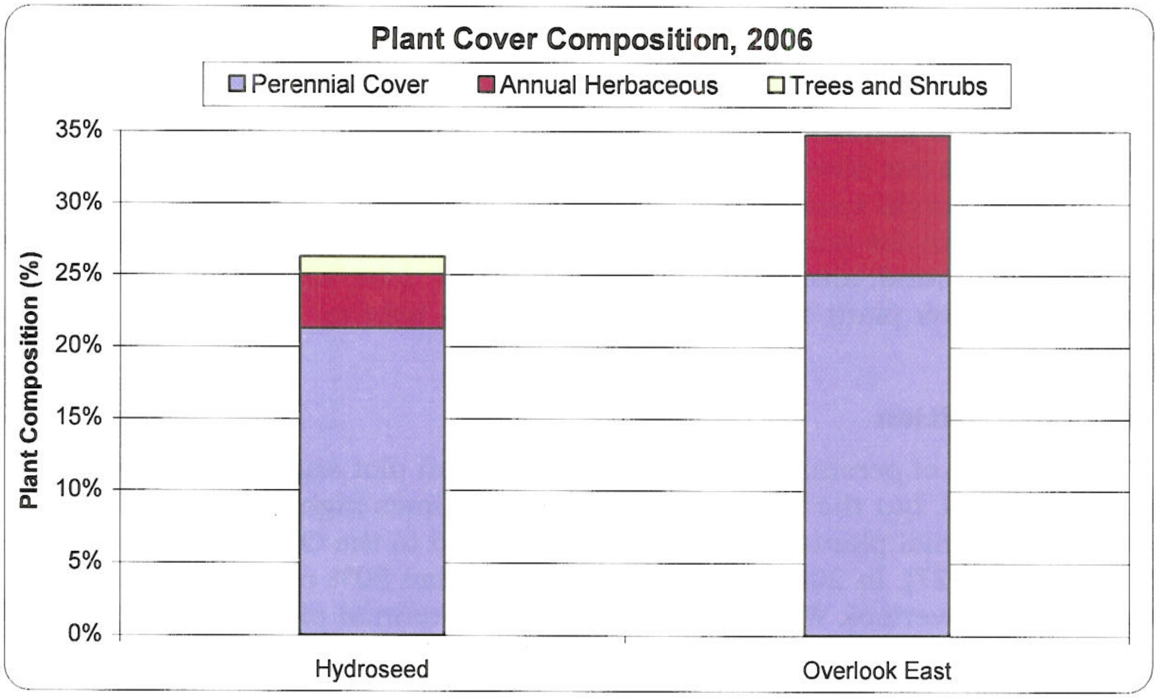


**Figure 26. Plant Cover Composition, 2006. Both plots are dominated by perennial plants. Plant cover was measured at the foliar (first hit cover) level.**

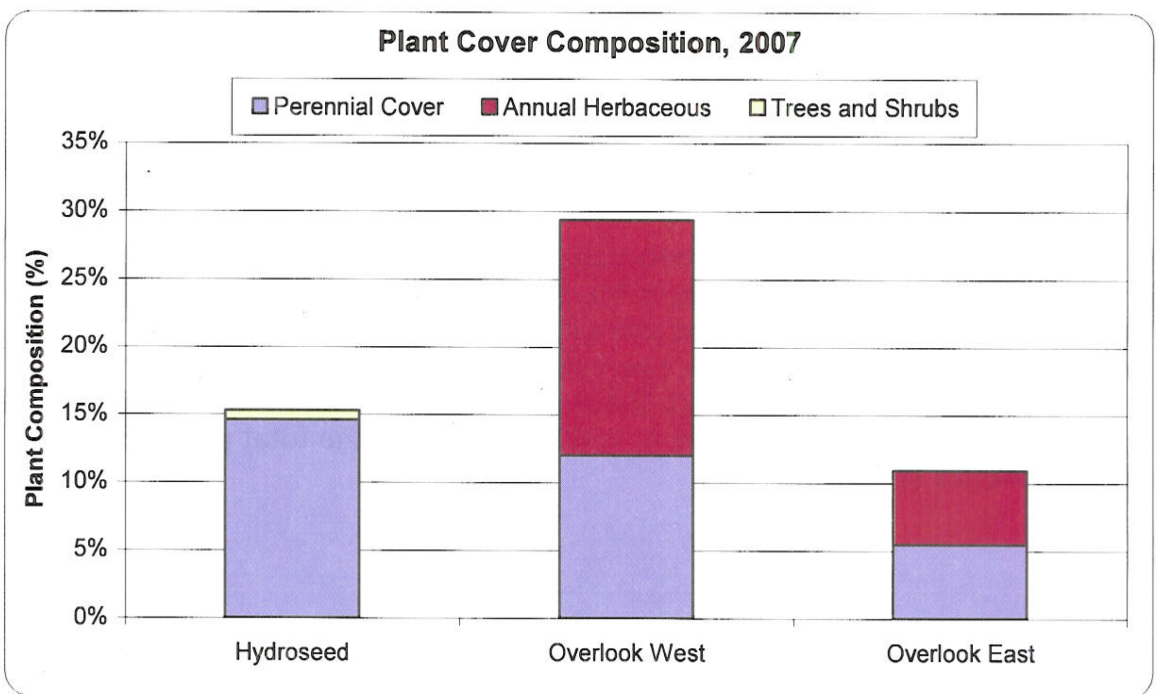


**Figure 27. Plant Cover Composition, 2007. The Hydroseed plot has the highest perennial plant cover. The perennial cover at the Overlook plots decreased from 2006. Plant cover was measured at the foliar (first hit cover) level.**

Seasonal variability of available water may be related to the decrease in cover by blue wild rye (*Elymus glaucus*) between 2006 and 2007 (Appendix A). The dominant species in 2006 and 2007 at the Overlook plots was blue wild rye, although it decreased markedly in 2007. In contrast, mountain brome did not perform very well and was only present in small quantities (Appendix A). Other perennial species did not increase in 2007, as shown by the overall decrease in perennial plant cover. The perennial plant cover decrease did not have a negative impact on infiltration, since neither Overlook plot produced any runoff in 2007 (Figure 17 and Figure 18).

In 2007, blue wild rye did not appear at many sites that had high blue wild rye cover in 2006, a high water year. One example of this trend is at test plots on nearby Lookout Mountain, located on the resort property.[7]

Perennial plant composition increased by 1.2 times at the Hydroseed plot between 2006 and 2007, from 80 to 95% (Figure 26 and Figure 27). The increase in cover did not affect the ability of the soil at the Hydroseed plot to infiltrate more water or to reduce sediment (Figure 17 and Figure 18).

## Soil Nutrients

The Overlook East and Overlook West plots had an average of 4.7 times higher organic matter and an average of 5.6 times higher total Kjeldahl nitrogen (TKN) levels than the Hydroseed plot (Figure 28). The average organic matter for soils at Overlook East and West plots in 2006 and 2007 was 8.9% and 10.8% respectively, while the average organic matter content for the Hydroseed plot was only 2.1%.

The two year average TKNs for Overlook East and West plots were 2,087 ppm and 4,844 ppm, respectively. The Hydroseed plot TKN was significantly lower (624 ppm). The Hydroseed site had very low values for both TKN and organic matter. Both levels were below those observed at successful re-vegetation sites throughout the Tahoe area.

In rainfall simulations, Overlook East and Overlook West generated little to no runoff, suggesting that healthy soil nutrient levels, and therefore healthy plants and root systems, may be related to higher infiltration rates and lower sediment yields (Figure 17 and Figure 18). The Hydroseed site produced high sediment yields and had low infiltration rates suggesting that the nutrient status of soil affects both plant production and the hydrologic function of the soil and plant community.

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[7] Monitoring and Assessment of Erosion Control Treatments in and around the Lake Tahoe Basin, Northstar-at-Tahoe Lookout Mountain Test Plots Site Report, unpublished, 2007.

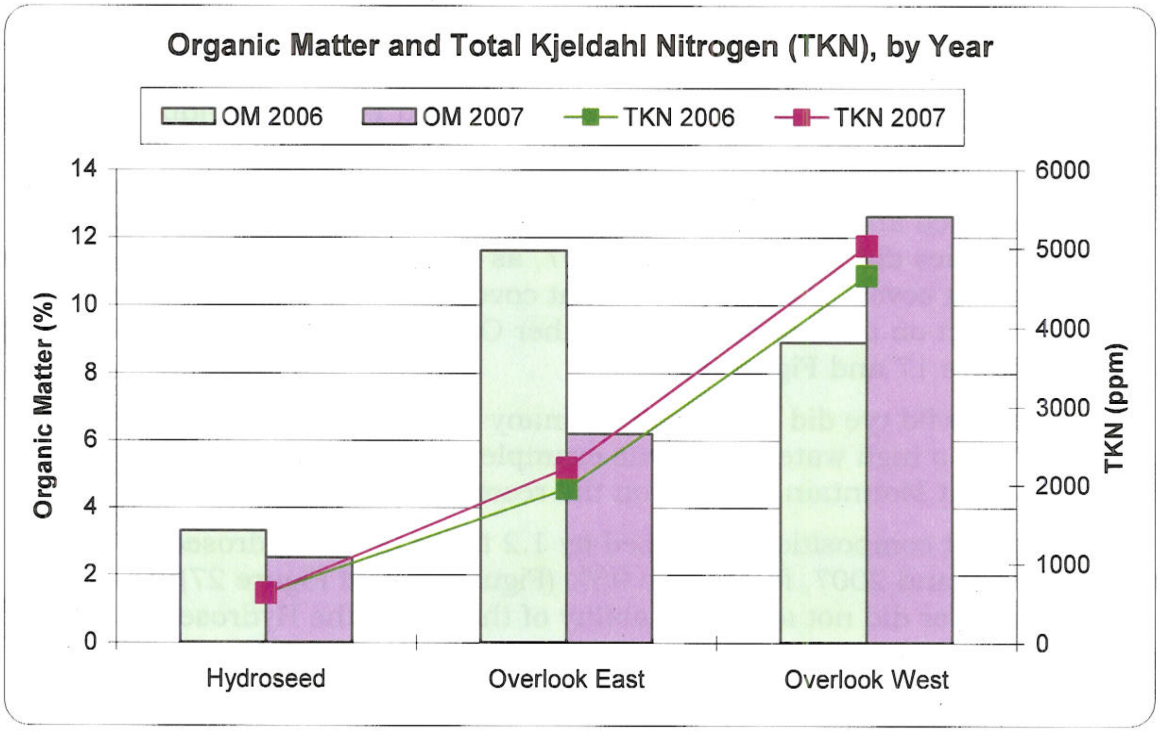


**Figure 28. Soil Organic Matter and Total Kjeldahl Nitrogen (TKN), by Year. The Hydroseed plot has the lowest TKN and organic matter, and also produced the highest sediment yield during rainfall simulations.**

## Shear Strength

At the Overlook West plot, shear strength was 1.3 times lower than at the Overlook East plot and 1.5 times lower than at the Hydroseed plots. This was most likely due to the lower proportion of coarse fragments in the soil at the Overlook West plot (Figure 29). The shear strength at Overlook West was 23 kPa, compared to 31 kPa at Overlook East and 35 kPa at the Hydroseed plot. The Overlook West plot had the lowest proportion of coarse fragments, as observed in soil sample holes. The percent of coarse fragments was 25%, as compared to 30% and 45%, respectively at the Hydroseed and Overlook East plots. When the shear vane contacts rocks or other coarse material in the soil, the material can prevent the vane from turning and a higher strength reading is produced. Overall, none of the plots produced shear strength readings of concern in terms of soil strength.

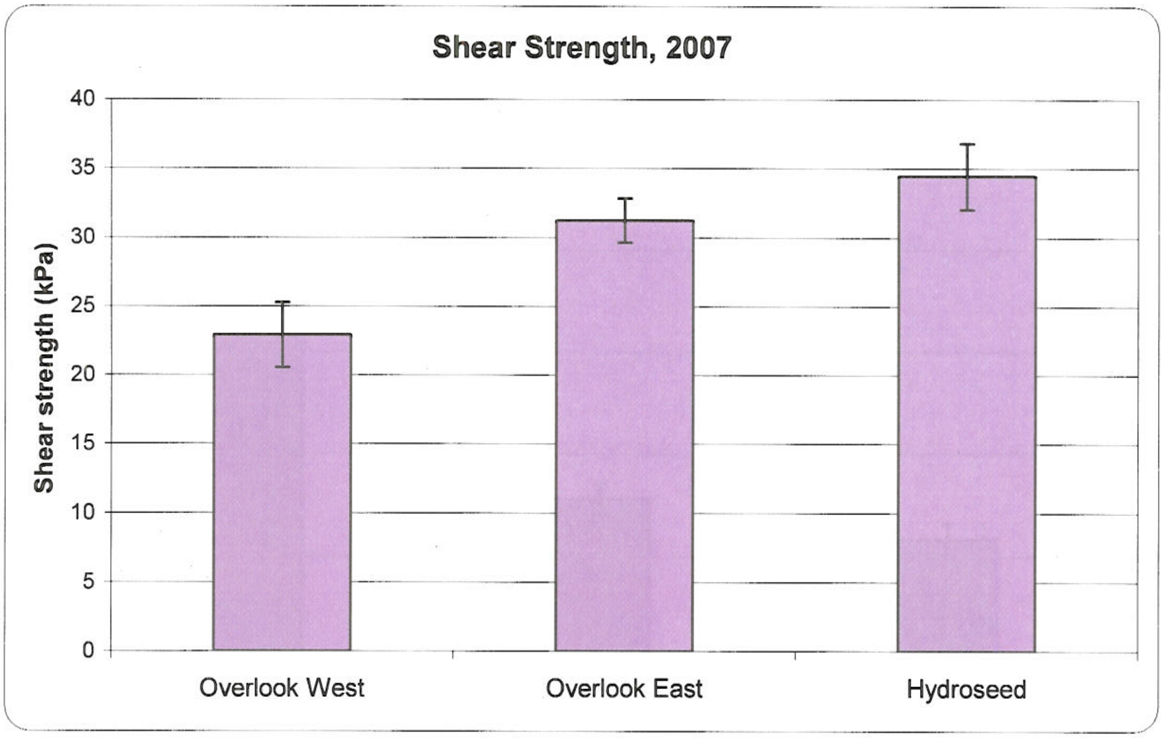


**Figure 29. Shear Strength, 2007. The Overlook West plot had a slightly lower shear strength than the other plots likely due to a lower proportion of woody material in the soil.**

## Soil Moisture

Over the two year period between 2006 and 2007, the Hydroseed plot had a soil moisture 2.7 times higher than at the Overlook plots (Figure 30). The average soil moisture at the Hydroseed plot was 19%, compared to an average of 7% at the Overlook plots. The difference in soil moisture can be explained by the different soil treatments. The untilled soil at the Hydroseed plot consisted of C horizon soil with a very high soil density (Figure 19). Highly dense volcanic soils are able to hold water better than soils with lower densities, but only in the top few inches of the soil. Highly dense soils prevent water from effectively moving down through the soil column, as seen by the low infiltration rates and high sediment yields observed at the Hydroseed plot (Figure 17 and Figure 18). The tilling and organic matter addition at Overlook East and Overlook West significantly changed the water-holding capacity and moisture distribution in the soil column.

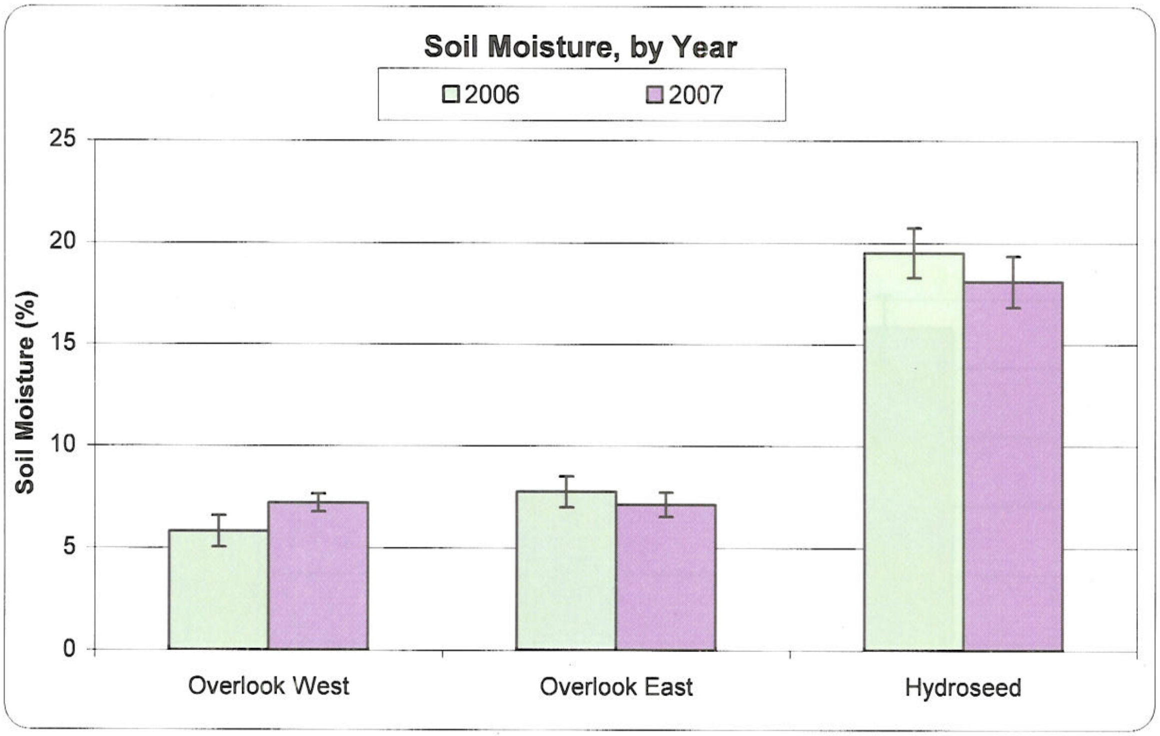


**Figure 30. Soil Moisture, by Year. The Hydroseed plot had the highest soil moisture, as measured in the top 4.7 inches of soil. This demonstrated reduced ability of the soil at the Hydroseed plot to infiltrate water deeply into the soil column.**

## Solar Exposure

The solar exposure ranged from 73% to 78% at the Hydroseed and Overlook plots. This exposure range is neither excessive nor deficient, and should not account for any variations between the plots.

## CONCLUSIONS

The following conclusions are grouped by soil, plant, and site characteristics that affect the erosion control capacity of a site.

### Infiltration

- The two year average sediment yield at the Hydroseed plot was 32 times higher than the two year average at the full treatment Overlook plots (Figure 16, Figure 17, and Figure 18).
- The infiltration rate at the Hydroseed plot was 1.4 times lower than the infiltration rates measured at the Overlook plots (Figure 17 and Figure 18).

**Soil Density**

- The two year average penetrometer DTR at the full treatment Overlook plots was 2.5 times deeper than the two year average penetrometer DTR at the Hydroseed plot (Figure 16, Figure 17, and Figure 18).
- The penetrometer DTRs measured along transects have been consistent at each site over the four year monitoring period (Figure 19).

**Mulch Cover and Depth**

- The ground cover by mulch at the Hydroseed plot was 5 times less than the ground cover by mulch at the Overlook plots (Figure 20)
- The mulch depth at the Hydroseed plot was 3.5 times shallower than the mulch depth at the Overlook plots (Figure 20).
- The proportion of bare ground at the Hydroseed plot was 8 times higher than at the Overlook plots (Figure 20 and Figure 21).

**Plant Cover and Composition**

- Overlook East and Overlook West exhibited foliar plant cover that was twice the foliar cover at the Hydroseed plot over the six year monitoring period (Figure 22).
- Plant cover and composition at each plot varied by year and was most likely dependent on a combination of precipitation during the previous year, the month during which the plots were sampled, and the prevalence of late-season snowpack (Figure 22).
- The proportion of perennial cover at the Hydroseed plot and Overlook plots was similar in 2006, but the Hydroseed plot had a 2 times higher proportion of cover by perennial plants in 2007 when compared to the Overlook plots (Figure 26 and Figure 27).
- Percent perennial plant cover decreased by 1.5 times between 2006 and 2007 at the Overlook East and West plots (Figure 26 and Figure 27).
- Seasonal variability of available water may be related to a decrease in cover by blue wild rye (Elymus glaucus) between 2006 and 2007 (Appendix A).
- Perennial plant composition increased by 1.2 times at the Hydroseed plot between 2006 and 2007, from 80 to 95% (Figure 26 and Figure 27).

**Soil Nutrients**

- The Overlook East and Overlook West plots had an average of 4.7 times higher organic matter and an average of 5.6 times higher total Kjeldahl nitrogen (TKN) levels than the Hydroseed plot (Figure 28).

**Soil Strength**

- At the Overlook West plot, shear strength was 1.3 times lower than at the Overlook East plot and 1.5 times lower than at the Hydroseed plot. This was most likely due to the lower proportion of coarse fragments in the soil at the Overlook West plot (Figure 29).

**Soil Moisture**

- Over the two year period between 2006 and 2007, the Hydroseed plot had soil moisture 2.7 times higher than at the Overlook plots (Figure 30).

## RECOMMENDATIONS

The following full treatment recommendations are for north-facing sites on volcanic parent material that have solar exposures between 73 and 78% with slope angles of approximately 27 degrees:

- Tilling: 12 inches (30 cm)
- Amendment: 4 inches (10 cm) aged wood waste (woodchips)
- Biosol: 1,500 lbs/acre (1,684 kg/ha)
- Seed Mix: 30% squirreltail, 40% blue wildrye, 20% mountain brome, 10% native forbs and shrubs
- Mulch: 2 inches (5 cm) of pine needle mulch, applied to 99% cover

### Full Treatment versus Surface Treatment

Full treatment is recommended over surface treatment for the following reasons. Full treatment plots exhibited the following when compared to the surface treatment plot:

- infiltration rates that were 1.4 times higher
- sediment yields that were 32 times lower
- penetrometer DTRs that were 2.5 times deeper
- plant cover that was twice as high
- mulch cover that was 5 times higher and 3.5 times deeper

- eight times less bare soil
- organic matter contents that were 4.7 times higher
- TKN levels that were 5.6 times higher
- soil moisture that was 2.7 times lower (shows more efficient water infiltration through the soil column)

**<u>Tilling versus No Tilling</u>**

Tilling to 12 inches (30 cm) is recommended over no tilling for the following reasons. Tilled plots exhibited:

- infiltration rates that were 1.4 times higher
- sediment yields that were 32 times lower
- penetrometer DTRs that were 2.5 times deeper
- plant cover that was twice as high
- organic matter contents that were 4.7 times higher
- TKN levels that were 5.6 times higher
- soil moisture that was 2.7 times lower (shows more efficient water infiltration through the soil column)

**<u>Biosol</u>**

Biosol is recommended at a rate of 1,500 lbs/acre (1,684 kg/ha) for the following reason:

- nutrients increased sufficiently from pre-treatment levels

**<u>Seed</u>**

The following seed mix is recommended:

30% squirreltail
40% blue wildrye
20% mountain brome
10% native forbs and shrubs

For the following reasons:

- blue wild rye was present in the highest quantities, so its proportion in the seed mix was increased from 31% to 40%
- mountain brome was decreased from 31% to 20% since it was only present in small amounts (Appendix A)

**Mulch**

Two inches (5 cm) of pine needle mulch is recommended for the following reasons.

- 1.25 inch (3.2 cm) application was patchy and provided less than 90% cover and less than 1 inch (2.5 cm) depth several years after treatment
- plots with 0.2 inches (5 mm) of mulch produced 32 times more sediment than plots with 0.7 inches (1.8 cm) of mulch.

## Appendix A

**Species list for Northstar Unit 7, 2006. The highlighted boxes represent the dominant species at each site, as observed ocularly.**

| Lifeform | Family | Scientific name | Common name | Annual/ Perennial | Native/ Alien | Invasive? | In OE/OW seed mix? | Seed Mix Percent | Overlook East (OE) | Overlook West (OW) | Hydroseed Plot (HYD) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Forb | Asteraceae | Achillea millefolium | Yarrow | Perennial | Native | | x | 0.5 | x | | x |
| Forb | Chenopodiaceae | Chenopodium albens | goosefoot | Annual | Alien | | | | | x | |
| Forb | Polemoniaceae | Collomia linearis | narrow-leaved collomia | Annual | Native | | | | x | x | |
| Forb | Boraginaceae | Cryptantha ambigua | Wilke's cryptantha | Annual | Native | | | | x | x | |
| Forb | Brassicaceae | Descurainia sophia | herb Sophia | Annual | Alien | Invasive | | | | x | |
| Forb | Papaveraceae | Eschscholzia californica | California poppy | Perennial | Native | | | | | | |
| Forb | Onagraceae | Gayophytum diffusum | prarie smoke | Perennial | Native | | | | x | x | x |
| Forb | Asteraceae | Lactuca serriola | devil's lettuce | Annual | Alien | Invasive | | | | x | |
| Forb | Brassicaceae | Lepidium campestre | English pepperweed | Annual | Alien | | | | x | x | x |
| Forb | Fabaceae | Lotus purshianus | Spanish lotus | Perennial | Native | | | | | | x |
| Forb | Fabaceae | Melilotus sp. | sweet clover | Annual | Alien | | | | x | x | x |
| Forb | Scrophulariaceae | Penstemon sp. | Penstemon | Perennial | Native | | | | | | x |
| Forb | Hydrophyllaceae | Phacelia hastata | silverleaf phacelia | Perennial | Native | | | | x | x | |
| Forb | Poaceae | Poa bulbosa | bulbous bluegrass | Perennial | Alien | | | | x | | x |
| Forb | Brassicaceae | Sisymbrium altissimum | tumble mustard | Annual | Alien | | | | x | | |
| Forb | Asteraceae | Tragapogon dubius | false salsify | Annual | Alien | | | | x | x | |
| Graminoid | Poaceae | Bromus carinatus | mountain brome | Perennial | Native | | x | 31.7 | x | x | x |
| Graminoid | Poaceae | Dactylis glomerata | orchard grass | Perennial | Alien | Invasive | | | | | x |
| Graminoid | Poaceae | Elymus elymoides | Squirreltail grass | Perennial | Native | | x | 31.7 | x | x | |
| Graminoid | Poaceae | Elymus glaucus | blue wildrye | Perennial | Native | | x | 31.7 | x | x | x |
| Graminoid | Poaceae | Festuca rubra | Red Fescue | Perennial | Native | | | | x | x | x |
| Shrub | Ericaceae | Arctostaphylos nevadensis | pinemat manzanita | Perennial | Native | | | | | | x |
| Shrub | Rosaceae | Purshia tridentata | Bitterbrush | Perennial | Native | | | | | | x |
| Shrub | Grossulariaceae | Ribes cereum | wax leaf currant | Perennial | Native | | | | | x | |
| Tree | Pinaceae | Abies concolor | white fir | Perennial | Native | | | | | x | |
| Tree | Pinaceae | Pinus jeffreyi | Jeffrey pine | Perennial | Native | | | | x | | |

**Species list and ocular estimates of composition for Northstar Unit 7, 2007. The highlighted boxes show ocular estimates of the dominant species at each site.**

| Lifeform | Family | Scientific name | Common name | Annual/ Perennial | Native/ Alien | Invasive? | In OW/OE seed mix? | Seed mix percent | Overlook West (OW) | Overlook East (OE) | Hydroseed (HYD) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Forb | Asteraceae | Achillea millefolium | yarrow | Perennial | Native | | x | 0.5% | < 5 | <5 | |
| Forb | Brassicaceae | Arabis holboelii | Holboel's rockcress | Perennial | Native | | | | T | | |
| Forb | Chenopodaceae | Chenopodium album | goosefoot | Annual | Alien | | | | T | | |
| Forb | Polemoniaceae | Collomia linearis | narrow-leaved collomia | Annual | Native | | | | T | 5 | |
| Forb | Boraginaceae | Cryptantha ambigua | Wilke's cryptantha | Annual | Native | | | | T | <5 | |
| Forb | Brassicaceae | Descurainia sophia | herb sophia | Annual | Alien | | | | T | | |
| Forb | Papaveraceae | Eschscholzia californica | California Poppy | Perennial | Native | | | | | | |
| Forb | Onagraceae | Gayophytum diffusum | prarie smoke | Perennial | Native | | | | < 5 | <5 | |
| Forb | Fabaceae | Lupinus lepidus | Lupine | Perennial | Native | | | | | T | |
| Forb | Fabaceae | Medicago lupulina | black medic | Annual | Alien | | | | | T | |
| Forb | Onagraceae | Oenothera elata | evening primrose | Perennial | Native | | | | T | | |
| Forb | Hydrophyllaceae | Phacelia hastata | silverleaf phacelia | Perennial | Native | | | | 5 | | |
| Forb | Polygonaceae | Polygonum douglasii | Douglas knotweed | Perennial | Native | | | | T | | |
| Forb | Brassicaceae | Sisymbrium altissimum | tansy mustard | Annual | Alien | | | | T | | |
| Forb | Asteraceae | Wyethia mollis | mule's ear | Perennial | Native | | | | T | | |
| Graminoid | Poaceae | Bromus carinatus | mountain brome | Perennial | Native | | X | 31.7% | 5 | | |
| Graminoid | Poaceae | Elymus elymoides | squirreltail grass | Perennial | Native | | X | 31.7% | 5 | 7 | |
| Graminoid | Poaceae | Elymus glaucus | blue wildrye | Perennial | Native | | x | 31.7% | 35 | 22 | |
| Graminoid | Poaceae | Festuca rubra | red fescue | Perennial | Native | | | | T | 7 | 15 |
| Graminoid | Poaceae | Poa secunda | Secund's bluegrass | Perennial | Native | | | | 5 | 5 | |
| Shrub | Rhamnaceae | Ceanothus velutinus | tobacco brush | Perennial | Native | | | | T | | |
| Shrub | Rosaceae | Purshia tridentata | bitterbrush | Perennial | Native | | | | <5 | | |
| Shrub | Grossulariaceae | Ribes cereum | wax leaf currant | Perennial | Native | | | | T | | |
| Tree | Pinaceae | Pinus jeffreyi | Jeffrey pine | Perennial | Native | | | | T | T | |
| Graminoid | Poaceae | Dactylis glomerata | orchard grass | Perennial | Alien | Invasive | | | | | <5 |
| Shrub | Ericaceae | Arctostaphylos patula | greenleaf manzinita | Perennial | Native | | | | | | T |
| Tree | Pinaceae | Abies concolor | white fir | Perennial | Native | | | | | | T |
| Forb | Fabaceae | Melilotus sp | sweet clover | Annual | Alien | | | | | | T |